Export sophistication, growth and the middle-income trap*

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9.1 Introduction

Structural transformation is at the heart of economic development. Successful developing countries progressively change their production structure, replacing low value added activities and unsophisticated goods with higher value added activities and more sophisticated products. A low-income country usually relies heavily on extractive resources, monoculture export and subsistence agriculture. Economic take-off starts with the shift of existing resources into processing activities and the production of basic manufacturing goods. During the "industrialization stage" mechanization spreads to the primary sector, thereby sustaining the fall in agricultural employment. At the same time, strong complementarities with the service sector ensure a steady rise in employment and output in commercial services, transportation and finance.

In these initial stages of diversification, the growth path invariably begins inside the global production frontier, with developing countries undertaking the manufacture of goods already produced elsewhere. Inside the frontier, countries are looking to catch up with those already at the frontier through rapid capital accumulation and technological adaptation in activities already in the industrial pipeline. These goods are also the ones that will drive export diversification.

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To sustain the development process, however, inside-the-frontier innovations are not enough. An emerging literature highlights the importance of capabilities and the need for a country to progressively increase its capability to develop and diffuse new products (and processes) and so to catch up (see the chapter by Nübler in this volume). Hence, it is the ability of a society and of firms to accumulate skills and knowledge, to combine the productive knowledge of its individuals and to develop collective competencies that determines its ability to diversify and increase internal value added and so to produce goods that are progressively more sophisticated and competitive in international markets, challenging the advanced competitors on the technological frontier.

Structural change and the development of capabilities are nevertheless challenging endeavours. Changing the economic structure of the economy requires the acquisition and refinement of productive knowledge. This may become a chicken-and-egg problem when learning takes place mainly in industries. A country cannot produce goods of which it has no knowledge, and it does not accumulate knowledge of products that it does not produce. Hausmann et al. (2011) acknowledge this, pointing out that countries move from the products that they already produce to others that are similar in terms of the knowledge required to produce them. Industrial development is assumed to be a gradual and path-dependent process, and countries are unable to jump into distant products.

Hausmann et al. (2011) examine differences among countries in terms of the complexity of products they export; they assume that a country's export structure reflects its capabilities to shift and diversify into products identified as related to products it already produces. Countries displaying a more complex and varied productive or export structure are assumed to have developed more capabilities. A country's economic complexity is measured by the number, variety, and rarity of the goods that it exports.

Hausmann et al. find that economic complexity is not perfectly correlated with each country's level of income but that the divergence between the expected and the actual level of economic complexity of a country is a good predictor of future economic growth. That is, countries with a more complex productive structure than that predicted by their level of income exhibit faster growth in subsequent years.

Nübler (in this volume) develops an explicit concept of capabilities, arguing that capabilities are not only created through learning in industries but also by knowledge acquired in formal education and in social networks such as families and communities, and, furthermore, that transformation of these knowledge systems in the labour force can open up options for jumping into distant products in the product space. Hence, a sustained process of productive transformation and of catching up from low- to middle- and eventually into advanced income ranks

requires deliberate and continuous learning at different places – in society, in schools, in firms – in order to expand options for gradually increasing sophistication of exports and for jumping into advanced technological regimes.

Historically, few middle-income countries have been able to enter the group of high-income economies. This suggests that, at middle levels of income, sustaining structural transformation and economic growth becomes more difficult. On one hand, these countries have reached a level of development high enough to prevent them from competing on the same ground with low-income countries. On the other hand, they still lack the proper knowledge structure in the labour force and the mix of institutional and production factors that would enable them to enter and compete in knowledge-intensive products. As a result, many of the countries that reach middle-income status are unable to continue the process of income convergence with rich economies and remain trapped in what has been called the middle-income trap.

For example, a majority of Latin American countries, although they had achieved a relatively high level of development as early as the end of the nineteenth century, have been held back by a failure to diversify and upgrade their manufacturing sectors. More recently, among the group of successful East Asian economies, growth performance has differed significantly; more constrained growth has been associated with the expansion of manufacturing activities inside global value chains such as performing simple assembly or processing of light industry products for export (e.g. garments, footwear, and foodstuffs) or the supply of electronic parts and components. In comparison to the high achievers such as China, Taiwan (China) and the Republic of Korea, middle achievers Malaysia and Thailand and low achievers Indonesia and the Philippines have found it difficult to establish domestic producers able to diversify and upgrade to the more technologically sophisticated parts of the chain (Ohno, 2009; Studwell, 2013).

The successful structural transformation experienced by the Asian first-tier newly industrialized countries (NICs) has been analysed recently by Jankowska, Nagengast and Perea (2012). Their study is based on the Product Space methodology (Hidalgo et al., 2007), which maps the relative proximity, or similarity, of traded products and shows that, in the case of the Asian NICs, structural transformation was a gradual process. New production was sequentially developed in industries (e.g. iron, steel and electronics) using skills and capabilities transferable with relative ease from existing industries. This strategic increase in high "connectivity" sectors[1] allowed undertaking a gradual yet systematic transition towards higher value added activities, especially those requiring similar technology and

[1] A high connectivity sector is one that can easily jump to other potential exports.

production techniques. By contrast, Latin American countries tend to be characterized by economic specialization in industries that are relatively far from high value added products, leading to less connectivity of their export profiles.

This chapter examines empirically this linkage between, on one hand, the dynamics and the composition of the export structure (as measured in particular by the level of sophistication of the exported products) and, on the other hand, economic growth. We do not look directly at structural change. In a sense we test the impact of the type of exports on growth without looking into the channel of transmission. To factor out the key features that characterize growth-enhancing products, we employ the measure of product sophistication developed by Hausmann, Hwang and Rodrik (2007). This measures sophistication of traded goods based on the income levels of countries exporting such goods. We then normalize this measure to a 0–100 scale. According to this index, the higher the average income of its exporters, the more sophisticated the product, i.e. a high (low) level of sophistication indicates that the product is exported mainly by rich (poor) countries.[2] In line with Hausmann, Hwang and Rodrik (2007), our illustrative regressions confirm that the sophistication of exports has a positive and significant effect on economic growth. However, we find no evidence of direct effects of technological intensity or export diversification on economic performances.[3]

The main contribution of this paper lies in the study of the dynamic variations in the export structure and the likelihood of remaining trapped at intermediate levels of income. We assume a Markov process and group countries on the basis of their export sophistication. Then we estimate how the probabilities of transition between groups change through time. Our results cast a shadow on the development perspectives of many developing countries, which are exposed to the risk of being unable to shift their production to highly sophisticated products. In line with the results of Hausmann et al. (2011), our analysis shows that, even in the long run, countries are unlikely to jump to products that are far from the knowledge embedded in the goods that they already produced. Knowing which export goods promote higher income levels is clearly not enough. The absence of productive knowledge

[2] This index is very similar to the sophistication index proposed by Lall, Weiss and Zhang (2006). There are small differences in the calculation process of each index. However, both of them capture the fact that a high sophistication level is correlated with high levels of per capita income.

[3] This is in line with the results of Imbs and Wacziarg (2003) and Klinger and Lederman (2006). They suggest that, while developing countries are characterized mainly by progressive diversification and inside-the-frontier innovation, more advanced economies tend to concentrate their exports and base their growth on a narrower set of products and services on the frontier, leading to a more specialized economic structure. Running regressions on a vast sample of countries at different levels of development therefore is likely to produce insignificant estimates for the coefficient gauging the impact of export diversification on economic growth.

and capabilities hinders countries from producing the goods that promote growth. These findings support the framework of catching up suggested by Nübler in this volume. Nübler argues that collective capabilities are not created automatically, but rather they require deliberate policies to enrich the knowledge structure in the labour force and to build "smart" enterprise routines and institutions in the country, in addition to creating the right incentives to invest in a new range of activities crucial to climbing the ladders of sophistication and to fostering development.

In a closely related contribution, Felipe, Kumar and Abdon (2010) provide empirical support for the contention that countries that are unable to upgrade and diversify their exports may become caught in a middle-income trap. They classify countries according to the sophistication and connectivity of their exports. They find that 120 of 154 countries are in a "bad product" trap, as they export mostly unsophisticated and unconnected products. They conclude that escaping this trap will require policy interventions aimed at addressing the market failures that are pervasive in many developing countries.

The remainder of this chapter is organized as follows. Section 9.2 describes the data on export sophistication and discusses the methodology. Section 9.3 summarizes the results of the growth regressions. Section 9.4 presents the dynamic results on sophistication and highlights the risk of middle-income-traps. Section 9.5 offers some concluding remarks.

9.2 Export sophistication index: Methodology and descriptive statistics

9.2.1 Methodology

To measure the quality of exports and its variations over time and to determine whether it is crucial to the process of development, we focus on a key characteristic of a country's export package: sophistication. We use a measure of export sophistication created by Hausmann, Hwang and Rodrik (2007). It is an outcomes-based measure of the sophistication of a country's export package – essentially the GDP per capita associated with the basket. This metric has two clear advantages over those used in the previous literature. First, it is defined at a highly disaggregated level (in the case of Hausmann, Hwang and Rodrik, HS 6-digits), which allows a fine-tuned evaluation. Second, it is outcomes-based, whereas past metrics were based on a priori assumptions of sophistication (e.g. all agriculture is less sophisticated, all manufactures are more sophisticated).

The export sophistication index attempts to capture the implied productivity of exported goods. The intuition behind it is that, when exporting a good, countries *reveal* their productivity levels, like the concept of revealed comparative advantage. For instance, in the absence of trade interventions, products exported by richer countries will have features that allow high wage earning producers to compete in world markets. Advanced technological content is certainly one of these features, but is not the only one. Other factors, such as the availability of natural resources, marketing or branding, quality of infrastructure, transportation costs or the degree of fragmentability of the production process,[4] may also play an important role in determining a country's export basket.

In this context Hausmann, Hwang and Rodrik (2007) developed a methodology to construct a quantitative index that ranks traded goods according to their implied productivity and that in a broad sense captures the different factors determining a country's export basket.[5] The overall assumption is that the higher the average income of the exporter, the more sophisticated the export. We follow Hausmann, Hwang and Rodrik (2007) and construct an export sophistication index by country for every second year during the period 1996–2008.

The index is constructed in three stages. The first stage involves measuring the GDP per capita (i.e. the implicit productivity level) associated with each exported product. This product level measure of sophistication is designated $PRODY_k$ and is calculated as the revealed comparative advantage (RCA)-weighted gross national income (GNI) per capita of each country exporting product *k*:

$$PRODY_k = \sum_j \frac{\frac{X_{kj}}{X_j}}{\sum_j \frac{X_{kj}}{X_j}} Y_j$$

where X_{kj} represents the value of exports of product *k* by country *j*; X_j the total value of exports of country *j*; and Y_j its GNI per capita. So, if a product accounts for a large share of poor countries' export baskets but a small percentage of rich countries' export baskets, then it will have a lower *PRODY*, as it is a "poor-country" export. Conversely, if a product accounts for a large share of rich countries' export packages but is not significant among poor countries' exports, it will have a higher *PRODY*, as it is a "rich country" export.

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[4] The fragmentability of production has intensified in recent years. When the production process is divisible, parts of it may be relocated to low-wage countries, reflecting the possibilities of separating segments of the value chain.

[5] A similar metric has been developed by Lall, Weiss and Zhang (2006).

In stage II we use this product level variable to measure the overall level of income associated with a country's export basket, i.e. the export sophistication level of country *j* during year *t* ($EXPY_{jt}$). This is done by evaluating the average of the *PRODY* of all goods that a country exports, each PRODY weighted by its share of total exports. Formally:

$$EXPY_{jt} = \sum_k \frac{X_{kjt}}{X_{jt}} PRODY_k$$

Naturally, since *PRODY* is measured using the GNI per capita of the typical exporter, rich countries have a high *EXPY* and poor countries have a low *EXPY*. This is by construction: rich countries export "rich country" goods and poor countries export "poor country" goods. There is significant variance in this relationship, however. There are many countries that have roughly equivalent levels of GNI per capita, but some of them have somehow managed to export a relatively more sophisticated set of products than others.

Finally, in stage III, we construct the export sophistication index, SI_{jt} by normalizing the export sophistication level, $EXPY_{jt}$, to a scale from 0 to 100 for every year. The country with the highest *EXPY* is set at 100 and the country with the lowest *EXPY*, at zero. The formula we apply for this normalization is:

$$SI_{jt} = \frac{EXPY_{jt} - EXPY_t(Min)}{EXPY_t(Max) - EXPY_t(Min)} * 100$$

SI_{jt} is, then, the normalized productivity level, on a scale 0–100, associated with country *j*'s export basket.

Sophistication measures of this kind display a positive correlation with technological intensity. Such a correlation, however, is not as close as would have been anticipated by standard trade theory. Lall, Weiss and Zhang (2006) show that there are cases where high technology products have low levels of sophistication, suggesting, for instance, that some production processes can be fragmented and, thus, parts of the process relocated to lower wage countries.[6] Likewise, there are low technology products with high sophistication levels as measured by the index, suggesting that the products have specific requirements for natural resource or logistics, or other needs that are out of reach for poorer countries – or that these products are subject to policy interventions.

[6] For instance, Srholec (2007) shows that the specialization of some developing countries in high-tech exports can be attributed to the effect on trade statistics of international fragmentation of production in electronics.

9.2.2 Descriptive statistics

We calculate the sophistication index (SI) for 158 countries for every second year during the period 1996–2008, i.e. 1996, 1998...2008.[7] The countries included are those for which data on exports by product, GNI per capita and per capita growth rates were available for the period under examination. The construction of the SI is based on two data sources: (i) UNCTADstat, for trade data by country for 259 products, using the Standard International Trade Classification (SITC) Rev. 3 at the 3-digit level, and (ii) World Development Indicators, for data on GNI and per capita growth rates.

Table 9.1 presents some descriptive statistics for our sophistication index, SI.

Table 9.2 presents the countries with the highest and the lowest average SIs in the sample for the analysed period.

In order to illustrate how the export sophistication level of some countries varied across time, figure 9.1 depicts the evolution of the SI for selected

Table 9.1 Descriptive statistics for the SI, 1996–2008

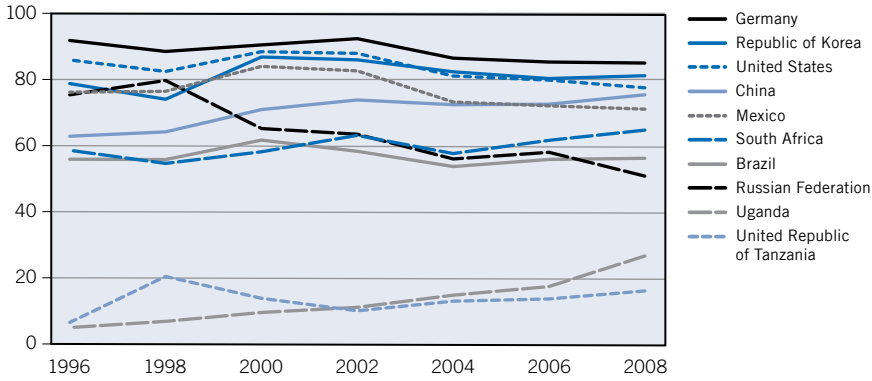
Year	No. of countries	Mean	Standard deviation
1996	158	43.06	25.39
1998	158	45.79	23.55
2000	158	48.21	24.99
2002	158	46.88	25.48
2004	158	44.33	23.59
2006	158	45.93	22.98
2008	158	44.65	23.88

Table 9.2 Top five and bottom five countries by average SI, 1996–2008

Country	Highest average SI	Country	Lowest average SI
Ireland	95.69	Burundi	7.42
Switzerland	95.66	Rwanda	4.70
Japan	94.82	Ethiopia	4.60
Finland	91.84	Mali	4.18
Singapore	90.53	Malawi	2.70

[7] A list of the 158 countries and territories in our analysis and their corresponding SI for each year can be found in the Annex to this chapter.

Figure 9.1 Evolution of the sophistication index for selected countries, 1996–2008



countries.[8] The countries selected include top exporters from the developed world: the United States and Germany; emerging economies: Brazil, China, Republic of Korea, Mexico and South Africa; and two countries from Africa with a relatively good performance within their region: the United Republic of Tanzania and Uganda.

In this sample Germany, the United States and the Republic of Korea present the highest SIs, the United Republic of Tanzania and Uganda the lowest. China notably increased its SI during the period analysed, in contrast with the deterioration of Russian Federation's SI. Mexico's SI has decreased in recent years, but it remains above Brazil's, while South Africa shows an upward trend since 2004.

9.3 Suggestive growth regression

We now turn to the analysis of the relationship between export sophistication and growth. The aim of this section is to assess the relative importance of sophistication as a source of growth as opposed to such usual suspects as export diversification or embedded technological intensity.

[8] Note that, since the SI has been normalized on a 0–100 scale, this figure actually shows the changes in export sophistication of each country in our sample *relative* to the others. Plotting the time series of the non-normalized index would not qualitatively change the figure, however. For consistency, we therefore employ for this merely descriptive excercise the same normalized index later used for the regressions and the simulations.

We build up a cross-country data set merging the data on sophistication described in the previous section with observations on other familiar determinants of growth. As a measure of export concentration, we employ the Herfindahl-Hirschman Index (HHI), based on UNCTADstat data. We use these data also to estimate highly technology-intensive goods as a share of total exports. All remaining independent variables are drawn from the World Development Indicators 2009.

We run a series of ordinary least squares (OLS) robust regressions with the growth rate as a dependent variable. All regressions include as explanatory variables the initial values (i.e. the values in 1998) of our sophistication measure (*SI*), the *HHI* and the share of total exports attributable to highly technology-intensive goods (*High Tech*).[9] Also, we control for the initial value of GDP per capita (*Initial GDP*), net inflows (new investment inflows less disinvestment) from foreign investors divided by GDP (*FDI*), gross capital formation (as a share of GDP), the sum of exports and imports of goods and services measured as a share of GDP (*Trade*), and, as a measure of human capital, the net rate of enrolment in primary school.

Table 9.3 summarizes the results of our analysis. In all the specifications the sophistication index is always positive and significant. In contrast, the share of highly technology-intensive goods in exports and the HHI index do not seem to affect economic performances once *Initial GDP* is included among the regressors.

These results, which confirm and update those of Hausmann, Hwang and Rodrik (2007), show that a country's relative level of export sophistication has significant consequences for subsequent growth. That is to say, if a country has a sophisticated export basket relative to its level of income, subsequent growth is much faster. Among characteristics of the exports structure, sophistication appears to be the primary determinant of economic development. Among the other growth determinants, physical capital appear to be a better predictor of growth than any of the other usual suspects; in fact, the parameters of both FDI and domestic capital formation are always positive and significant, in contrast to the variables intended to capture the impact of human capital and trade.

These results are only suggestive, since the time horizon is short and they may suffer from potential bias due to omitted variables. They are, however, in line with the work of Hausmann, Hwang and Rodrik (2007), which uses panel regressions over the period 1962–2000 and controls for country and year fixed effects.

[9] Our product classification by technology intensity is based on Lall (2000).

Table 9.3 Cross-country growth regressions, 1998–2008

Variables	(1) Growth	(2) Growth	(3) Growth	(4) Growth	(5) Growth
EXPY	0.0147***	0.0153***	0.01**	0.01**	0.01*
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)
HHI	0.00002	−0.00001	−0.00002	−0.00002	−0.00002
	(0.00003)	(0.00003)	(0.00002)	(0.00002)	(0.00003)
Tech/ exports	0.004	−0.0065	−0.002	−0.0015	−0.0015
	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
GDP per capita	−0.00003***	−0.00003***	−0.00003***	−0.00003***	−0.00003***
	(0.000001)	(0.000001)	(0.000001)	(0.000001)	(0.000001)
FDI/GDP		0.022***	0.014***	0.014***	0.0135**
		(0.005)	(0.004)	(0.005)	(0.005)
Capital formation			0.03***	0.03***	0.03***
			(0.005)	(0.005)	(0.005)
Trade/GDP				0.0003	0.0003
				(0.001)	(0.001)
Schooling					−0.0007
					(0.001)
Constant	0.434**	0.46***	−0.065	0.052	0.067
	(0.154)	(0.145)	(0.15)	(0.16)	(0.16)
Observations	168	168	168	168	168
R-squared	0.08	0.19	0.35	0.35	0.35

9.4 The degree of export sophistication as a Markov process: Methodology and results

The capacity to improve one's export structure and the degree of sophistication of exported products are therefore of paramount importance for the overall process of economic development. This section proposes a simple simulation exercise aimed at exploring the potential evolution of export structures around the globe and its consequences.

In order to study the likelihood of climbing the ladder of export sophistication, we assume that the sophistication of the export structure in each country evolves over time as an exogenous first-order Markov process, where the conditional probability distribution of future states of the process depends only upon

the present state, not on the sequence of events that preceded it.[10] In fact, at any point of time, *t*, the state of the evolutionary process of a country's export structure is described entirely by the characteristics of the present state (e.g. the capital stock, the behavioural rules of each firm and the public policy in place) and not by the entire history. Therefore, this state can be used to predict short-term changes and the new structure that will emerge at time $t + 1$.

Stochastic Markov processes have been widely used in economic modelling. In their seminal contribution, Nelson and Winter (1982) made use of a Markov process to describe technological evolution, arguing that "verbal account of economic evolution seems to translate naturally into a description of a Markov process – though one in a rather complicated state space" (ibid., p. 19). More recently, Markov processes have been used to model productivity changes over time (Fernandes and Isgut, 2005; Michael and Hao, 2009) and switches of growth regimes. Jerzmanoswki (2006) estimates a Markov-switching model of growth with four such regimes: miracle growth; stable growth; stagnation; and crisis.

In this paper we consider five possible states, or sophistication groups, based on the value of the sophistication index (SI) for each country, with each group covering 20 percentage points on the SI scale. The groups are classified in descending order, with Group 1 containing countries with the highest level of export sophistication. The group classification criteria are outlined in table 9.4.

We then classify the 158 countries and territories in our sample into their corresponding export sophistication group for every year. Table 9.5 lists the number of countries in each sophistication group by year.

In order to construct the transition probability matrix, we first calculate the probabilities of switching sophistication group every two years during the period analysed. In other words, we construct six transition probability matrices: 1996–98, 1998–2000, 2000–02, 2002–04, 2004–06 and 2006–08. Next, we

Table 9.4 Export sophistication groups: classification criteria

Export sophistication group	Criteria
Group 1	$80 \leq SI \leq 100$
Group 2	$60 \leq SI < 80$
Group 3	$40 \leq SI < 60$
Group 4	$20 \leq SI < 40$
Group 5	$0 \leq SI < 20$

[10] This is the so-called Markov property.

Table 9.5 Number of countries per export sophistication group, 1996–2008

Group	1996	1998	2000	2002	2004	2006	2008
1	16	15	24	25	14	13	14
2	25	28	23	23	26	31	35
3	33	44	47	42	44	48	28
4	53	53	45	43	54	47	55
5	31	18	19	25	20	19	26
Total	158	158	158	158	158	158	158

Table 9.6 Average transition probability matrix

Initial state/future state	1	2	3	4	5	Total
1	0.83	0.16	0.01	0.00	0.00	1
2	0.10	0.78	0.11	0.01	0.00	1
3	0.00	0.09	0.77	0.13	0.01	1
4	0.00	0.01	0.11	0.77	0.10	1
5	0.00	0.01	0.03	0.23	0.72	1

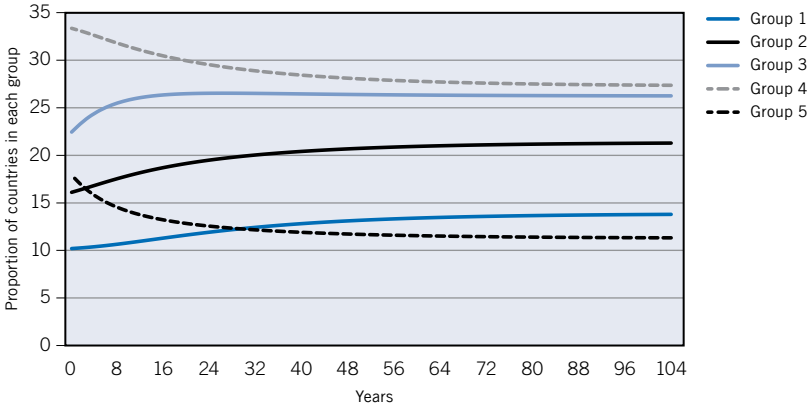
average the transition probabilities of those six matrices and construct an average transition matrix, M, shown in table 9.6.

This average transition matrix can be used to conduct our simulation exercise and explore the future evolution of export sophistication over time and across countries. Starting with M, we calculate the probabilities that a country starting in Group i will be in Group j after a given number of periods, n. Furthermore, based on this result, we calculate the proportion of countries in each group after n periods.[11] Figure 9.2 shows the evolution of the proportion of countries in each export sophistication group.

Figure 9.2 shows the evolution of the proportion of countries in each export sophistication group beginning in 1996. The projection begins in year 12 (2008). It reveals two notable trends. The first is that, over the next 30 years, the proportion of countries in the highest sophistication groups will increase slightly. Group 1 will increase its proportion of countries from 10 per cent to 12 per cent,

[11] The probabilities that the Markov chain, starting in Group i, will be in Group j after n steps are given by the power of the average transition probability matrix, $M^{(n)}$. Thus, if the initial distribution of countries in each group is given by a vector g, where the sum of the vector equals 1, then the distribution of countries after n periods, $g^{(n)}$, will be given by $g^{(n)}=g\,M^{(n)}$. For more on Markov chains and their properties, see, for instance, Grinstead and Snell (1997, Chapter 11).

Figure 9.2 Projected evolution of the proportion of countries in each export sophistication group



whereas Group 2 will grow from 16 per cent to 20 per cent. The second trend is that, within the same period, the proportions of countries in the lowest sophistication groups, 4 and 5, will decrease at a greater rate than the groups 1 and 2. The proportion of countries in Group 4 decreases from 34 per cent to 29 per cent, and the proportion in Group 5 drops from 20 per cent to 12 per cent. Both trends are positive, considering that they point in the same direction: increasing levels of export sophistication.

However, the chart also highlights a problem: getting stuck in intermediate sophistication levels and being unable to climb even higher. After the first 30 years, the proportion of countries in each group changes only slightly and remains practically unchanged after year 80, where the probabilities tend to reach a steady state.

As shown in section 9.3 and in Hausmann, Hwang and Rodrik (2007), export sophistication predicts subsequent economic growth. Thus, the inability to climb the sophistication ladder has important implications for growth. In our case, as transition probabilities reach their steady state, 65 per cent of the countries will remain in middle or low sophistication export levels, which implies lower growth rates.

We then perform an exercise like the one above but separating countries according to their initial income level. In other words, we calculate two transition probability matrices for each pair of years, one for the 20 per cent richest countries and another for the remaining 80 per cent. After obtaining the pair of matrices for 1996–98, 1998–2000, 2000–02, 2002–04, 2004–06 and 2006–08, we calculate two average probability matrices, one for each set of countries. To summarize the result of this exercise, we find that, in the steady state, the richest

countries will remain in the top two sophistication groups, with probabilities above 80 per cent, whereas the other countries will remain, with 80 per cent probabilities, in the middle and lower sophistication groups.

These results show that, under the dynamics observed in the last two decades, climbing the ladder of sophistication is not an easy task. For middle- and low-income countries there is a risk of getting stuck in middle or low levels of export sophistication. This can have important implications for growth. In fact, over the course of economic development, low value added, labour-intensive assembly operations must be progressively replaced by more technologically sophisticated activities. This requires introducing new or improved goods and services and developing or adopting innovative production processes and better modes of business operation.

9.5 Concluding remarks

Successful developing countries progressively change their production structure, replacing low value added goods with more sophisticated activities and a wider array of products. As countries undergo this transformation, three important changes are seen. First, production diversification increases in line with rising income levels, but subsequently it slows down and then even reverses as countries become more specialized as they enter a post-industrial stage. Second, while investment becomes less important at high levels of income and the importance of innovation grows, for most developing countries operating inside the production frontier, the links between a rapid pace of investment and technological adaptation are crucial to successful diversification. Third, educational systems shift their focus along with structural changes in the economy, from developing workers' skills to adopt and adapt technology to preparing and enabling workers to develop new processes and products.

These changes do not occur automatically, and, thus, many middle-income countries fail to increase the sophistication of their production and export structures. This in turn adversely affects growth performance. Our analysis confirms that climbing the export sophistication ladder is extremely difficult for developing countries. As transition probabilities approach their steady state, in fact, most countries get stuck in the intermediate levels of export sophistication. We have shown that, under the export dynamics observed during the period 1996–2008, only very few middle-income countries will eventually manage to climb to the top of the sophistication ladder.

An emerging literature identifies productive capabilities as the determinants and drivers of productive transformation dynamics and increasing export sophistication. Capabilities are not distributed exogenously, but they can be actively built up over time. Industrial policies in particular may play an important instrumental role, facilitating evolution of a knowledge structure that provides the options for moving along trajectories of progressive sophistication in the product space. Education and training policies are central to expanding the options for jumping into products and technologies that are more distant from the existing export structure (Nübler, 2013). Developing the right set of capabilities enables middle-income countries to move up the value chain and break into fast-growing markets for knowledge- and innovation-based products and services.

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Annex

Export sophistication index for 158 countries and territories, 1996–2008

Country/territory	SI 1996	SI 1998	SI 2000	SI 2002	SI 2004	SI 2006	SI 2008
Albania	31.56	36.68	38.61	35.20	35.23	40.67	39.07
Algeria	83.17	100.00	73.75	71.20	61.77	61.52	42.11
Angola	58.89	55.12	56.23	55.28	53.33	56.35	34.31
Antigua and Barbuda	37.43	87.05	98.95	93.29	45.65	24.99	55.69
Argentina	52.10	57.68	58.04	52.99	48.24	51.47	53.33
Armenia	35.72	29.11	34.52	32.72	29.91	29.72	35.14
Australia	56.22	59.48	60.39	61.69	55.53	55.00	64.06
Austria	85.92	84.20	84.42	87.81	81.09	80.35	82.61
Azerbaijan	39.61	51.29	54.83	55.21	50.31	52.97	35.09
Bahrain	57.83	58.00	54.42	55.89	51.73	57.73	76.47
Bangladesh	25.90	30.06	29.26	25.81	24.67	25.04	18.28
Belarus	65.50	66.75	64.75	64.28	61.80	61.43	64.57
Belgium	75.70	75.03	77.95	81.68	79.81	78.97	78.31
Belize	21.20	22.54	21.09	11.50	14.97	20.30	23.04
Benin	3.42	4.47	6.27	14.79	12.46	20.63	9.85
Bhutan	20.77	22.60	20.73	19.41	26.19	45.93	11.87
Bolivia, Plurinational State of	37.38	43.02	40.09	42.20	39.25	43.36	29.07
Bosnia and Herzegovina	49.25	45.32	50.67	60.09	54.39	57.24	61.32
Botswana	35.90	43.57	23.09	23.52	27.15	24.69	28.13
Brazil	55.87	55.76	61.65	58.27	53.65	55.80	56.15
Bulgaria	52.81	55.62	54.78	52.99	51.01	50.26	55.16
Burkina Faso	3.12	8.55	14.01	8.72	0.89	25.99	18.11
Burundi	6.31	0.00	0.00	10.25	8.47	20.75	10.83
Cambodia	24.45	31.34	29.17	24.18	25.32	24.40	11.41
Cameroon	33.07	33.12	45.33	39.15	35.10	41.97	30.83
Canada	80.21	80.89	82.42	80.72	71.11	70.80	64.82
Cabo Verde	37.02	49.67	53.22	31.21	25.85	44.40	48.51
Central African Republic	8.02	13.20	16.61	9.78	5.77	7.62	12.17
Chad	1.02	4.68	7.83	6.81	49.63	39.25	25.09
Chile	31.70	35.66	39.31	34.68	31.51	27.44	30.69
China	62.82	64.14	70.88	73.79	72.35	72.50	75.36
Colombia	41.77	44.00	51.65	52.82	47.42	47.65	49.04
Comoros	16.96	25.08	5.67	3.10	4.31	7.63	0.48
Congo	56.98	49.45	54.16	53.56	47.06	50.81	34.68
Costa Rica	31.56	45.92	58.71	60.14	63.01	69.43	61.34
Côte d'Ivoire	14.78	20.81	24.05	14.26	22.48	28.49	24.41
Croatia	54.99	53.79	58.92	57.81	57.78	55.82	56.72

Country/territory	SI 1996	SI 1998	SI 2000	SI 2002	SI 2004	SI 2006	SI 2008
Cyprus	57.20	61.55	65.72	69.44	68.86	67.22	67.40
Czech Republic	76.54	79.40	84.18	86.22	79.70	80.47	82.54
Democratic Rep. of the Congo	14.52	14.94	26.19	24.46	20.24	20.27	15.80
Denmark	78.16	76.41	79.74	80.71	76.60	74.22	74.74
Djibouti	32.52	47.47	41.84	51.71	32.65	38.53	30.44
Dominica	31.67	37.06	37.19	38.89	31.80	34.30	31.54
Dominican Republic	34.79	38.65	40.90	41.49	38.36	40.85	48.39
Ecuador	33.39	33.11	45.18	39.90	40.44	43.97	32.81
Egypt	43.89	44.61	46.72	42.99	44.48	51.74	48.53
El Salvador	35.50	35.40	44.05	40.11	39.11	37.21	38.24
Equatorial Guinea	36.39	47.90	53.63	56.55	53.36	57.85	37.86
Eritrea	22.08	24.41	23.95	18.33	24.24	26.83	19.11
Estonia	60.61	63.14	77.39	66.96	66.61	64.07	65.92
Ethiopia	2.54	4.61	5.63	6.34	4.72	1.71	9.84
Fiji	22.15	26.46	27.21	29.46	27.50	27.17	30.26
Finland	93.13	89.38	100.00	95.72	88.71	86.75	88.33
France	80.67	79.40	83.91	84.52	78.06	78.07	77.21
Gabon	51.88	51.37	52.97	48.96	44.07	48.14	31.74
Gambia	23.93	22.09	19.74	24.40	30.18	13.62	28.53
Georgia	35.27	39.53	42.03	40.93	34.64	37.67	37.34
Germany	91.79	88.46	90.44	92.33	86.43	85.26	84.96
Ghana	17.41	23.59	21.31	8.39	10.17	13.79	9.74
Greece	46.82	50.75	54.30	54.13	55.13	55.48	58.66
Grenada	21.90	42.59	50.02	29.15	26.13	39.51	37.48
Guatemala	30.25	32.51	34.53	36.11	39.09	34.07	32.58
Guinea	16.24	17.84	20.00	19.41	15.71	20.81	10.35
Guinea-Bissau	18.98	34.84	37.76	23.10	22.99	14.10	14.96
Guyana	15.43	17.01	16.05	15.94	16.43	14.98	13.10
Honduras	24.18	26.05	26.00	24.27	22.53	22.82	25.03
Hong Kong SAR (China)	76.19	75.11	81.53	81.01	76.89	78.03	79.29
Hungary	68.01	77.81	86.98	88.73	83.67	82.13	82.97
Iceland	37.65	44.31	43.77	45.44	41.88	43.12	56.65
India	41.20	40.47	46.81	48.41	49.74	51.10	54.83
Ireland	95.67	84.90	93.27	100.00	100.00	100.00	100.00
Israel	61.66	61.55	70.38	62.35	62.70	58.99	68.04
Italy	79.29	77.79	80.81	79.01	75.97	76.06	76.65
Jamaica	21.50	24.59	24.92	21.94	20.76	23.93	27.67
Japan	100.00	93.42	98.77	98.07	90.15	89.47	88.69
Jordan	31.16	38.54	61.11	45.19	42.80	43.40	49.91
Kazakhstan	50.61	48.94	55.49	51.63	47.95	50.50	38.26
Kenya	24.08	25.48	23.88	35.78	29.46	26.63	27.27

Country/territory	SI 1996	SI 1998	SI 2000	SI 2002	SI 2004	SI 2006	SI 2008
Kiribati	3.71	11.95	13.10	20.51	25.70	29.73	27.00
Korea, Republic of	78.76	74.00	86.78	85.92	82.31	80.27	81.12
Kyrgyzstan	32.27	31.08	22.08	25.72	28.67	34.52	43.72
Lao People's Dem. Rep.	23.79	28.43	23.53	25.93	24.71	25.49	22.82
Latvia	53.87	51.89	54.27	54.57	55.91	60.82	64.62
Lebanon	52.94	51.31	48.93	47.01	45.46	42.79	49.36
Lesotho	30.15	34.54	31.72	28.61	25.15	24.63	18.18
Lithuania	57.55	59.57	58.50	55.69	55.99	58.89	61.97
Luxembourg	89.69	91.42	95.37	94.22	87.07	85.06	85.83
Madagascar	11.49	22.76	29.27	17.69	23.28	24.91	22.48
Malawi	3.51	4.41	6.63	1.73	4.31	0.00	0.00
Malaysia	81.94	77.07	85.74	84.53	75.13	75.83	64.17
Maldives	28.31	34.50	31.04	24.35	29.35	14.60	11.87
Mali	0.00	8.81	6.45	4.90	4.79	2.83	5.62
Mauritius	28.99	30.89	31.22	29.46	30.08	36.30	34.87
Mexico	76.15	76.41	83.95	82.59	73.17	72.01	71.01
Moldova, Republic of	37.19	41.01	40.65	40.17	38.51	45.31	45.39
Mongolia	19.90	28.83	28.31	21.88	20.74	20.43	17.87
Morocco	26.16	33.26	36.38	34.95	35.79	38.71	29.66
Mozambique	17.81	27.41	24.63	45.72	51.56	41.60	62.79
Namibia	25.51	29.79	26.67	26.21	28.88	26.86	26.53
Nepal	15.97	23.75	36.39	37.82	33.18	36.15	31.83
Netherlands	80.77	81.01	77.70	80.10	75.93	74.35	73.54
New Zealand	62.53	65.51	63.45	63.95	62.51	63.44	65.38
Nicaragua	33.30	20.07	19.35	33.34	23.79	16.08	24.89
Niger	25.78	26.29	17.45	13.62	7.03	12.15	2.18
Nigeria	60.46	59.58	60.02	57.74	53.89	55.84	33.31
Norway	70.76	73.93	65.54	66.01	60.63	62.53	50.03
Pakistan	31.32	34.47	37.57	36.17	34.94	31.66	31.86
Panama	26.32	29.44	33.17	31.35	22.29	19.20	20.13
Papua New Guinea	14.11	22.71	24.18	17.85	20.46	20.10	9.18
Paraguay	19.14	22.52	26.22	25.32	23.22	29.47	33.42
Peru	30.13	32.69	33.43	28.22	24.68	22.97	23.50
Philippines	78.75	77.24	88.60	87.08	78.85	79.80	72.71
Poland	62.69	64.28	71.67	70.36	68.95	68.76	72.88
Portugal	63.46	67.02	72.07	71.16	67.34	68.45	68.89
Romania	53.00	53.40	55.85	53.95	52.90	57.20	63.84
Russian Federation	75.35	79.69	65.15	63.43	55.95	57.96	50.76
Rwanda	8.65	3.08	2.13	0.00	4.57	3.50	6.52
Saint Kitts and Nevis	42.08	61.36	63.36	63.74	59.54	72.41	81.45
Saint Lucia	30.72	35.19	39.20	46.12	41.82	51.04	57.02
Saint Vincent and the Grenadines	29.91	31.35	32.72	27.83	28.31	29.52	38.99

Country/territory	SI 1996	SI 1998	SI 2000	SI 2002	SI 2004	SI 2006	SI 2008
Samoa	36.57	30.54	33.93	33.99	28.59	28.73	30.21
Saudi Arabia	64.11	64.85	60.42	61.72	58.94	58.67	39.63
Senegal	30.95	41.95	33.17	38.47	34.53	39.25	45.23
Seychelles	48.52	48.87	49.83	40.21	38.04	37.19	45.41
Sierra Leone	13.64	18.13	5.49	46.04	0.00	44.48	31.43
Singapore	97.04	86.61	93.84	93.62	87.05	86.70	80.77
Slovakia	70.99	74.00	78.12	76.66	73.09	74.98	78.51
Slovenia	79.54	79.28	83.71	82.82	80.06	79.10	82.15
Solomon Islands	8.63	18.55	19.08	11.93	6.71	4.31	2.17
South Africa	58.57	54.60	58.12	63.08	57.58	61.58	64.67
Spain	76.71	76.17	80.18	77.96	72.06	71.30	73.18
Sri Lanka	31.03	28.62	29.79	28.16	27.85	27.59	24.73
Sudan	12.77	18.48	40.99	38.96	40.09	43.10	33.44
Suriname	20.49	26.25	45.79	17.90	15.09	15.46	67.50
Swaziland	43.89	41.79	40.31	33.75	38.64	50.07	50.23
Sweden	94.85	90.07	95.82	94.27	87.96	84.68	85.42
Switzerland	96.90	89.48	98.54	95.27	97.68	96.95	95.68
Syrian Arab Republic	50.12	44.22	50.66	48.25	45.44	45.58	37.03
Tajikistan	22.11	47.44	45.56	51.64	36.28	60.08	54.28
Tanzania, United Rep. of	6.50	20.41	13.81	10.02	12.93	13.61	16.03
Thailand	65.26	65.30	71.56	72.23	67.27	68.23	65.55
The FYR of Macedonia	41.23	44.24	47.60	43.68	41.85	42.10	43.04
Togo	14.84	14.99	20.49	21.43	23.89	29.51	26.57
Tonga	16.32	20.03	31.29	12.73	15.42	13.97	16.40
Trinidad and Tobago	48.95	57.44	58.12	54.83	58.24	57.79	49.92
Tunisia	40.05	41.76	43.66	42.46	41.36	46.87	45.27
Turkey	48.38	49.61	54.41	55.22	55.05	57.28	60.00
Turkmenistan	71.30	46.58	67.73	60.91	63.40	61.38	39.77
Uganda	4.95	6.83	9.52	11.07	14.75	17.36	26.60
Ukraine	57.89	57.04	59.54	61.48	58.06	60.58	63.08
United Kingdom	85.99	82.59	86.80	89.33	81.22	82.18	79.55
United States	85.90	82.41	88.40	87.88	81.04	79.79	77.47
Uruguay	48.61	52.79	54.84	50.16	48.19	46.73	47.63
Uzbekistan	12.53	27.54	28.72	24.37	25.31	31.39	38.50
Venezuela, Bolivarian Republic of	56.59	60.66	58.08	57.92	52.21	56.09	35.74
Viet Nam	36.37	37.53	43.73	41.07	41.58	45.03	37.09
Yemen	59.28	57.89	58.76	55.65	51.86	54.90	37.72
Zambia	26.89	27.77	33.54	27.79	30.21	24.18	26.14